the RP group
Research • Planning • Professional Development for California Community Colleges

Maximizing Math Throughput of Students Who Did Not Complete Algebra 2 in High School

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Executive Summary

In this paper we investigate how the one-year math throughput rate[1] of community college students varies according to the highest level of math completed in high school, with a particular focus on the implications of successfully completing Algebra 2[2] while in high school. Community college math throughput rates for students with different levels of math coursework completion in high school are compared, with the primary contrast being differences in throughput among students who enter their community college math sequence via Intermediate Algebra relative to the throughput of students who begin their math coursework in a transferable, college-level math class.[3]

Key Findings

Among community college students taking their first math class in fall 2019 who had not successfully completed Algebra 2 in high school, only 8% of those beginning in Intermediate Algebra[4] completed any transferable math within one year (i.e., they achieved an 8% throughput rate). By contrast, those who had not completed Algebra 2 in high school who nonetheless began in a transferable, college-level statistics or liberal arts math (SLAM) class experienced a 37% throughput rate while those who entered directly into a transferable, college-level B-STEM[5] math class achieved a 30% throughput rate.

Math sequence entry points and throughput rates in the California community college system have shifted over time resulting in **large increases in the number of community college students completing transferable, college-level math** within one-year of enrolling in their first math class. Prior to fall 2019, 65% of students began their math sequence in the community college in Intermediate Algebra. After the implementation of AB 705[6] in fall 2019, the percentage of students beginning in Intermediate Algebra dropped to 20%. This shift of students from a low throughput entry point (i.e., Intermediate Algebra) to a higher throughput entry point (i.e., transferable math) means that the **overall throughput of the fall 2019 cohort**

[1] Throughput rate is the percentage of a given cohort of students who complete a key gateway course—in this case a transferable, college-level math course—within a designated time frame.

[2] "Algebra 2" is used here as an umbrella term for high school courses coded *as* Algebra 2, which includes courses with titles like "Algebra II" and "Intermediate Algebra" as well as equivalent courses like Integrated Math 3.

[3] In California, Intermediate Algebra is considered to be a 'college-level' course because it fulfills the math requirements for certain local associate degrees. However, the majority of degrees, including all STEM degrees and all transfer-oriented degrees, require completion of a math class that is both college-level and articulated to the university. We use the phrase "transferable, college-level math class" to distinguish key gateway math classes from community college Intermediate Algebra classes, which while technically college-level, do not transfer.

[4] For clarity, we use "Intermediate Algebra" to refer to the community college version of this course and "Algebra 2" to refer to the high school version of this course.

[5] B-STEM math classes are calculus-oriented classes that are required for some Business programs and for all STEM (e.g., Biology, Computer Science, Engineering, Math, Physical Science) degree programs.

[6] A law requiring colleges to place students in a way that maximizes the likelihood of completing gateway college-level Math (and English) classes within a year of an initial attempt in the sequence.

increased to 38%, ten percentage points higher than the average throughput rate of the historical, pre-AB 705 cohorts (28%).

The data also revealed that **students who are pursuing a STEM program of study have much greater throughput when allowed to begin their community college math studies in a transferable, college-level math class regardless of their level of math progression in high school.** Even those STEM-oriented students who had only completed Algebra 1 in high school had a much higher throughput rate (38%) when allowed direct access to transferable, college-level math classes at the community college vs. Intermediate Algebra (12%).

Statistical models that included controls for the influence of high school GPA on math throughput revealed that **student entry point into the math sequence (i.e., transferable, college-level math vs. Intermediate Algebra) is a powerful factor in predicting completion of a gateway math class.** Starting directly in a transferable, college-level math class provides a boost to throughput rates approximately equivalent to the effect of gaining two grade points in cumulative high school GPA.

After taking into account the influence of high school GPA and the level of math class completed in high school, **students who entered directly into a transferable, college-level math class were 6.7 times more likely to complete a gateway math class in their first year than were students who began their community college math pathway in Intermediate Algebra.** This finding was true for all students, regardless of their highest level of high school math completed or program of study.

Discussion

Following the implementation of AB 705 in fall 2019, there was a large shift upwards in the percentage of community college students beginning their math coursework in a transferable, college-level math class, including many who had not completed Algebra 2 while in high school. Concomitant with this shift was an increase in the one-year math throughput rate to 38 percent, up from an average of 28 percent in previous years.

While it is true that students who complete Algebra 2 in high school have greater math throughput rates than those who do not, it does not follow that students who did not complete Algebra 2 in high school are best served by being placed into Intermediate Algebra at the community college. In fact, students who have not completed Algebra 2 in high school are much *less* likely to achieve math throughput within one year if they begin in Intermediate Algebra than if they enroll directly in a transferable, college-level math class. **This large difference favoring direct access to transferable, college-level math holds true across all levels of high school GPA and math completion and for students in both STEM and non-STEM programs of study.**

Recommendations

Given the findings of this study, we recommend colleges direct all students to begin their math studies in transferable, college-level math regardless of whether they completed Algebra 2 (or the equivalent) in high school. Along with expanding access to transferable, college-level math, colleges should place students with lower high school GPAs and lower levels of high school math attainment into corequisite or concurrent remediation with holistic support.

The intensity and level of support could be scaled according to students' level of engagement with math in high school:

High School Math Profile	Typical Throughput Results	Recommendation
Successfully completed a high school math class subsequent to Algebra 2, (e.g., precalculus, statistics) with at least a "C-"	Highest average throughput rate	Transferable, college-level math placement; Additional support optional
Successfully completed Algebra 2 in high school (but not higher) with at least a "C-"	Middling throughput rate	Transferable, college-level math placement; Moderate level of additional support needed
Successfully completed less than Algebra 2 in high school	Lowest average throughput rate	Transferable, college-level math placement; Highest intensity of additional support needed, including holistic support for non-academic issues[7]

Additionally, while the completion rate of Algebra 2 among California high school graduates who go on to enroll in community college has trended up over time, **only 62% to 65% of California community college students successfully completed Algebra 2 or higher while in high school**. Moreover, many California high school students (37%) who go on to enroll in community college take no math classes in their senior year. Therefore, it is recommended that high schools adopt policies congruent with increasing the proportion of students who enroll in four years of math in high school (note that this is not a call to change university admission policy). Following this guidance would improve graduating students' quantitative reasoning and numeracy skills, increasing their likelihood of success in postsecondary math courses.

Future Research

An implication of the observed upward trend in math throughput rates is that recent innovations in community college math instruction (e.g., in assessment, placement, curriculum, pedagogy) are resulting in large gains in the number and percentage of students completing

[7] See Scrivener et al. (2015) for evidence of the effectiveness of holistic support strategies on increasing completion rates among students with multiple background factors associated with lower likelihood of completion.

transferable, college-level math. Future research should examine in greater detail to what extent specific innovations (e.g., placement practices, just-in-time remediation, self-remediation, informal learning, enhanced transfer-level classes, corequisite remediation, embedded tutoring, required supplemental instruction, professional development, equity initiatives) are uniquely or in combination supporting or promoting further increases in math throughput. While other contemporaneous research (e.g., Brohawn et al., 2021) shows that these reforms have closed equity gaps in access to transferable, college-level math, additional research is needed to highlight positive outliers and practices that are associated with eliminating equity gaps in math outcomes.

Introduction

Since the advent of the California Community Colleges Chancellor's Office's (CCCCO) default placement rules in July 2018,[8] the role of Algebra 2[9] in determining the placement of Business & Science, Technology, Engineering, and Mathematics (B-STEM) students has been a topic of discussion and debate. Many California community colleges have implemented B-STEM corequisite remediation courses that do not presume or require the completion of Algebra 2 in high school, while other colleges have opted to channel B-STEM students who did not complete Algebra 2 while in high school into degree-applicable but non-transferable math classes that emphasize intermediate algebra skills (aka, Intermediate Algebra). For transfer-oriented students, Intermediate Algebra is seen as a precursor to enrollment in transferable, college-level math that enhances the likelihood that students will ultimately complete a transferable, gateway math class. The sixty-four-thousand-dollar question, as they say, is **which of these approaches results in more students successfully completing a transferable, college-level math class?**

Completion of Algebra 2 in high school is only one signal of students' academic capabilities. Students' overall history of academic success, as encapsulated by their cumulative high school GPA, is also a potent predictor of future academic success in college (Bahr et al., 2019; Hayward, 2017; Scott-Clayton et al., 2014; Willett et al., 2008). While GPA is conceptually distinct from a student's course-taking history, there is a tendency for students with higher GPAs to have also completed higher math coursework levels (Jaffe, 2012; Willett et al., 2018). Moreover, students with greater high school GPAs tend to perform better in any class—including transferable college-level B-STEM math classes—than students with lower high school GPAs (Chen, 2009; Chen & Ho, 2012; Hayward, 2017; Willett et al., 2008). Therefore, it is necessary to study high school GPA and high school math course-taking together to better understand their unique contributions to subsequent success in community college math classes.

Moreover, there is evidence that there is a positive correlation between high school GPA and the level of math completed during high school (see Adelman, 2006; Allen et al., 2017; Koger et al., 2004). This implies that students who have not completed Algebra 2 in high school may also be more likely to have a lower overall high school GPAs than those who have. Parke (2012), for example, reported a moderately strong point biserial correlation ($r = 0.43$) between the completion of advanced high school math coursework and higher GPA.

Additional evidence of the relationship between higher-level math coursework completion and GPA comes from the publicly available High School Longitudinal Study of 2009 data set (U.S. Department of Education, 2021). The study's nationally representative sample provides evidence of the strong positive relationship ($r\ (21{,}868) = 0.644$, $p < .001$) between overall high

[8] See California Community Colleges AB 705 Memo (http://bit.ly/AB705-Implementation-Memo)

[9] Also commonly known as Intermediate Algebra and Algebra II. Integrated Math 3 also covers essentially the same objectives and is therefore considered an equivalent class to Algebra 2, as well.

school GPA and highest-level math course completed (author's analysis, see Appendix A). Due to the possibly confounding relationship between high school GPA and highest-level math class completed, any analysis of the role of Algebra 2 in the success of students in community college B-STEM classes must also evaluate and account for the association between high school GPA and highest math course completed in high school and their joint influence on outcomes at the community college level.

In this paper, we present the results from a detailed analysis of high school math course-taking patterns and high school GPA designed to provide a better understanding of how students navigate the high school math curriculum and how those experiences and achievements subsequently relate to the completion of transferable, college-level math.

In the California context, the fall 2019 cohort is particularly important for understanding which community college math placement maximizes throughput for students with various levels of high school math attainment. In fall 2019, public community colleges in California were required to shift assessment and placement procedures as well as curriculum in response to the passage of AB 705.[10] Subsequent guidance from the California Community Colleges system office stipulated that students could not be placed into Intermediate Algebra unless a) they had not completed it in high school and b) they were pursuing a Business or STEM (B-STEM) program of study. In response to the requirements of AB 705, most colleges in the system began offering transferable, college-level placements with concurrent remediation to students who prior to fall 2019 would have most likely been placed in multi-term remediation sequences (Brohawn et al., 2021; Cuellar Mejia et al., 2020; Hern et al., 2020; Hern et al., 2019). This change represents a significant shift in assessment, placement, curriculum, and pedagogy. By comparing the outcomes of the fall 2019 cohort to prior cohorts, we can evaluate the current and ongoing context for students who are experiencing the results of these widespread and comprehensive changes in placement and curriculum, increasing our understanding of how to maximize math throughput for students who did not successfully complete Algebra 2 while in high school.

Methods

The following research questions (RQs) are evaluated and discussed:

> **RQ 1:** Among community college students, what is the distribution of the highest level of math course completed while in high school? What proportion did not successfully complete Algebra 2?

[10] In March 2020, approximately halfway through the spring term, the COVID-19 pandemic required that virtually all instruction move to an online format. Students were allowed to drop spring 2020 courses without incurring a withdrawal or "W" notation on their transcripts. Instead, they received an Excused Withdrawal or "EW". These "EWs" were included as non-passing grades in the calculation of throughput. The impact on 2019-2020 throughput rates was small to negligible likely due to the tendency of students who were performing well prior to the pandemic to stay enrolled. According to the Chancellor's Office Data Mart the average pass rate for math classes in spring 2019 was 55.7%, while in spring 2020 it was 58.7% (counting the "EW" as a non-passing grade).

RQ 2: Among students who did not complete Algebra 2 in high school, what is the throughput rate of those who enrolled directly in either a transferable, college-level SLAM or B-STEM-pathway math class at a community college and how does it compare to the throughput rate of those who initially enrolled in Intermediate Algebra at a community college?

RQ 2.1: How do historical patterns of throughput for community college students who did not successfully complete Algebra 2 in high school compare to the throughput results attained after the implementation of AB 705?

RQ 3: What is the effect of different levels of high school math course attainment on math throughput at the community college after controlling for variations in high school GPA?

RQ 4: Among students who have declared[11] a STEM program[12] of study and who have not completed Algebra 2 in high school, which placement— transferable, college-level math vs. Intermediate Algebra—maximizes the probability of completing a STEM pathway math class at the community college?

The base data set of California community college (CCC) students with both high school transcript data and community college math enrollment data available was developed with the assistance of the CCCCO and Ed Results Partnership/CalPASS. It includes all CCC students who enrolled in either a transferable, college-level math class or an Intermediate Algebra class at the community college from summer 2010 through summer 2020. To answer our research questions, we developed and analyzed an initial sample of students (Sample 1) all of whom had four years of reported high school GPA and at least two years of detailed high school math enrollment data. We used Sample 1 to explore patterns of high school math coursework and determine how much information was needed to characterize students' highest level of high school math completed. Sample 1 allowed us to understand how specific high school math coursework and GPA patterns influenced subsequent community college math success. To develop a clear picture of the order, flow, and pattern of high school math course-taking, the sample included only students for whom the following was true:

- GPA was reported for each high school grade level (9th through 12th grades)
- Math course codes and descriptions were available for at least two grade levels
- A community college math enrollment was recorded

The above parameters resulted in a file with 440,920 student cases (Sample 1). This sample was used to evaluate RQ 1. Based on this evaluation of Sample 1, we developed a larger sample

[11] Students may select or declare a program of study on their application and/or during subsequent interactions such as meetings with counselors.
[12] Here we focus on STEM programs because some Business programs' math requirements are satisfied with Statistics or Liberal Arts Math. See Appendix B for the list of programs identified as STEM.

(Sample 2) by leveraging the patterns observed in the first sample to include more students. We were able to expand the sample by developing and adopting rules regarding what constitutes sufficient information to ascertain the highest math class completed in high school, even for those student cases where high school transcript information was less complete. Including students with less complete (but sufficient) transcript information increases the statistical power of our analyses. The expanded Sample 2 was developed using the following parameters:

- Overall cumulative high school GPA reported for at least one grade level[13]
- Math course enrollment record for at least 11th grade or 12th grade
- If a student's highest math class in 11th or 12th grade was Geometry, they must also have a prior math class on record (e.g., if Geometry in 11th grade and no math in 12th grade they must also have a lower-level math class enrollment record)
- A community college math enrollment was recorded

The expanded sample requirements are sufficient to allow for a determination of whether a student has completed Algebra 2 in high school. The need for additional information for students whose last class was Geometry is due to an alternative pathway taken by some students in which Geometry is taken after Algebra 2 rather than before it. The expanded sample includes 1,251,165 students and was used to evaluate RQ 2, RQ3, and RQ 4. An important benefit of the expanded sample is improved statistical power, which allows us to investigate the outcomes of specific subsets of students and those with less common math pathways (particularly RQ 4).

The primary outcome of interest is successful completion of transferable, college-level math coursework at the community college within one year of an initial math enrollment.

[13] Due to the high levels of correlation of cumulative high school GPA across high school years (see Appendix C for additional details).

Description of Samples

Table 1. Samples 1 and 2: Descriptive Statistics

Characteristic	Sample 1		Sample 2	
	Count or Average	Percentage or Standard Dev.	Count or Average	Percentage or Standard Dev.
Female	228,369	51.8%	648,532	51.8%
Male	212,551	48.2%	602,633	48.2%
Asian	51,977	11.8%	161,587	12.9%
Black	19,211	4.4%	61,977	5.0%
Latinx	241,730	54.8%	624,459	49.9%
Native American	1,265	0.3%	4,602	0.4%
Pacific Islander	1,775	0.4%	6,333	0.5%
White	88,132	20%	276,307	22.1%
Multi-Ethnic	16,283	3.7%	40,234	3.2%
Unknown Ethnicity/race	20,547	4.7%	75,666	6.0%
Completed Alg. 2 or Higher in High School	286,371	64.9%	769,492	61.5%
Program of study available	137,937	31.3%	401,996	32.1%
Declared STEM Program of Study	24,842	5.6%	74,120	5.9%
Number of HS Math Courses Recorded	3.5	0.630	2.64	0.998
Number of HS Math Courses Passed	2.5	1.151	1.86	1.141
High School GPA	2.70	0.614	2.68	0.654
Age at Time of First CCC Math Enrollment	18.7	0.397	18.8	4.896
Total Headcount	**440,920**	**100%**	**1,251,165**	**100%**

Overall, student characteristics were similar across both samples. Sample 2 had the same percentage of female and male students as in Sample 1 (51.8% and 48.2%, respectively). While the distribution of ethnic groups was generally similar between Sample 1 and Sample 2, the latter had a somewhat higher percentage of Asian, Black, Native American, Pacific Islander, White and unknown ethnicity/race students and a correspondingly lower percentage of Latinx students (49.9% vs. 54.8%) and multi-ethnic students (3.2% vs. 3.7%). In Sample 2, 61.5% of students had successfully completed Algebra 2 or better in high school, while in Sample 1 this value was somewhat higher at 64.9%. Sample 2 included 74,121 students with a STEM program of study, nearly three times as many as in Sample 1 (n = 24,842). The average high school GPA of students in Sample 2 was 2.68, very close to the 2.70 average GPA of Sample 1. Age at the time of first community college math enrollment was also quite similar between Sample 2 (18.8 years) and Sample 1 (18.7 years).

The largest difference between the two samples lies in the number of high school math courses recorded per student (3.50 in Sample 1 and 2.64 in Sample 2). This difference was expected due to the intentional inclusion of student cases with less complete high school transcript information in Sample 2. In addition to the other similarities between Sample 1 and Sample 2, the average number of high school math courses passed as a percentage of all math courses taken was also similar for Sample 1 (1.86/2.64 = 70.5%) and Sample 2 (2.50/3.50 = 71.4%), which indicates that the students included in Sample 2 can be considered comparable to the students in Sample 1.

Results

Results are presented below in the order of the research questions.

RQ 1: Among community college students, what is the distribution of the highest level of math course completed while in high school? What proportion have not successfully completed Algebra 2?

As shown in Table 2 below, 35.8% of Sample 1 had not successfully completed Algebra 2 while in high school; 15.6% had completed no higher than Geometry (or Integrated Math 2); 10.7% had completed no higher than Algebra 1; and 2.2% had not progressed beyond Pre-Algebra. About one in five of those who had not completed Algebra 2 in high school had no successful completions of any high school math course, despite having a minimum of at least two detailed course records in the data set (7.3%).[14]

[14] Cf. Jaffe (2012) in which 47% of students in one community college district completed no math in their senior year of high school, as well as the NCES 2012/2017 Beginning Postsecondary Survey sample of 22,500 students in which 19.8% of students pursuing associate's degrees completed or attempted less than Algebra 2 as their highest math class in high school (https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2020504).

Table 2. Highest Math Completed in High School

	Frequency	Percent	Cumulative Percent
No successful math record	32,351	7.3	7.3
Arithmetic (also Consumer Math & Vocational Math)	4,197	1.0	8.3
Pre-Algebra	5,115	1.2	9.4
Algebra 1/Integrated Math 1	47,223	10.7	20.2
Geometry/Integrated Math 2	68,881	15.6	35.8
Algebra 2/Integrated Math 3[15]	108,278	24.6	60.3
Trigonometry	18,989	4.3	64.6
Statistics	34,602	7.8	72.5
Math Analysis[16]	17,909	4.1	76.6
Precalculus	64,625	14.7	91.2
Calculus	38,750	8.8	100.0
Total	**440,920**	**100.0**	

An examination of enrollment patterns across the four high school grade levels shows that the most common enrollment pattern from 9th through 12th grade was: Algebra 1 (9th grade); Geometry (10th grade); Algebra 2 (11th grade); and no math enrollment (12th grade).[17] The headcount for enrollment in these most typical courses is shown in bold for each grade level in Table 3 below. Typical 12th grade math courses were Statistics (13.9%) and Algebra 2 (13.8%). It was also very common for students not to enroll in any math course at all in their senior year (36.5%). In the 11th grade, Geometry (17.8%) and Precalculus (13.5%) were typical courses, in addition to the most common class, Algebra 2 (37.3%). It is noteworthy that 36.8% of 11th graders in the sample completed a math course that would receive transfer credit if taken at a community college.

[15] *Integrated Mathematics IV (college preparatory)* classes with course group state code 2430 are also included here as they are the final course of a sequence that covers the integrated math topics in four years instead of three.
[16] Math Analysis is a post-Algebra 2 course that is available at some high schools in California. It covers the following topics: trigonometry, conic sections, inequalities, and the exploration and interpretation of algebraic, trigonometric, logarithmic, exponential, rational and polynomial functions.
[17] For the purposes of this analysis Integrated Math courses are counted alongside their traditional sequence equivalents (i.e., Integrated Math I = Algebra 1; Integrated Math II = Geometry; Integrated Math III = Algebra 2).

Table 3. Distribution of Math Enrollments by High School Grade for Sample 1 (n = 440,920)

Course	9th Grade Count	9th Grade Percent	10th Grade Count	10th Grade Percent	11th Grade Count	11th Grade Percent	12th Grade Count	12th Grade Percent
Arithmetic	4,331	1.0%	3,526	0.8%	7,070	1.6%	20,899	4.7%
Pre-Algebra	26,538	6.0%	6,731	1.5%	2,775	0.6%	1,522	0.3%
Algebra 1	**241,976**	**54.9%**	73,696	16.7%	25,491	5.8%	10,980	2.5%
Geometry	115,765	26.3%	**197,850**	**44.9%**	78,680	17.8%	18,809	4.3%
Algebra 2	23,767	5.4%	104,773	23.8%	**164,512**	**37.3%**	60,712	13.8%
Trigonometry	5,724	1.3%	17,189	3.9%	23,947	5.4%	14,410	3.3%
Math Analysis	219	0.1%	4,354	1.0%	18,594	4.2%	11,505	2.6%
Statistics	63	0.0%	900	0.2%	11,838	2.7%	61,202	13.9%
Precalculus	3,542	0.8%	14,338	3.3%	59,370	13.5%	44,564	10.1%
Calculus	116	0.0%	2,001	0.5%	16,005	3.6%	35,490	8.0%
No enrollment	18,879	4.3%	15,562	3.5%	32,638	7.4%	**160,827**	**36.5%**

The Sankey diagram in Figure 1 contains all high school math course transitions with at least 200 students[18] and represents a visual summary of the math pathways of 99.5% of all high school course transitions of the students in Sample 1 (*N* = 440,920). The diagram allows for a qualitative and quantitative inspection of math course-taking among high school students. Each set of vertical, colored bars represents a year of math enrollment, beginning with 9th grade math enrollment on the left and ending with 12th grade math enrollment on the right. The gray lines between the colored bars represent the flow of a group of students from one course to the next with the number of students making that transition indicated by the thickness of the gray line. The relative volume of students in a particular course at a given grade level is represented by the length of the colored bars.

Thus, it is easy to see at a glance that the most common pathway through high school math curriculum is to begin in Algebra 1 in 9th grade, and then transition to Geometry in 10th grade, and then to Algebra 2 in 11th grade, and then to no math coursework in 12th grade. Very infrequently utilized transitions with 200 students or fewer were not included in the diagram to facilitate visual inspection and analysis. In total, 433,787 cases were selected for the diagram, and 7,133 (0.5%) were excluded.

Students may be missing coursework in a given year due to skipping math in that year or incompleteness of their administrative records. Students who were missing data on their enrollment for a given year were denoted in the Sankey diagram simply by an underscore followed by the grade level (i.e.., "_12"). In general, we interpreted a year without a math class entry as a year in which the student did not enroll in math for some reason. Skipping math was most commonly observed in the senior year (36.5% of cases) and junior year (7.4% of cases), though there were also cases with no reported math enrollments in the sophomore year

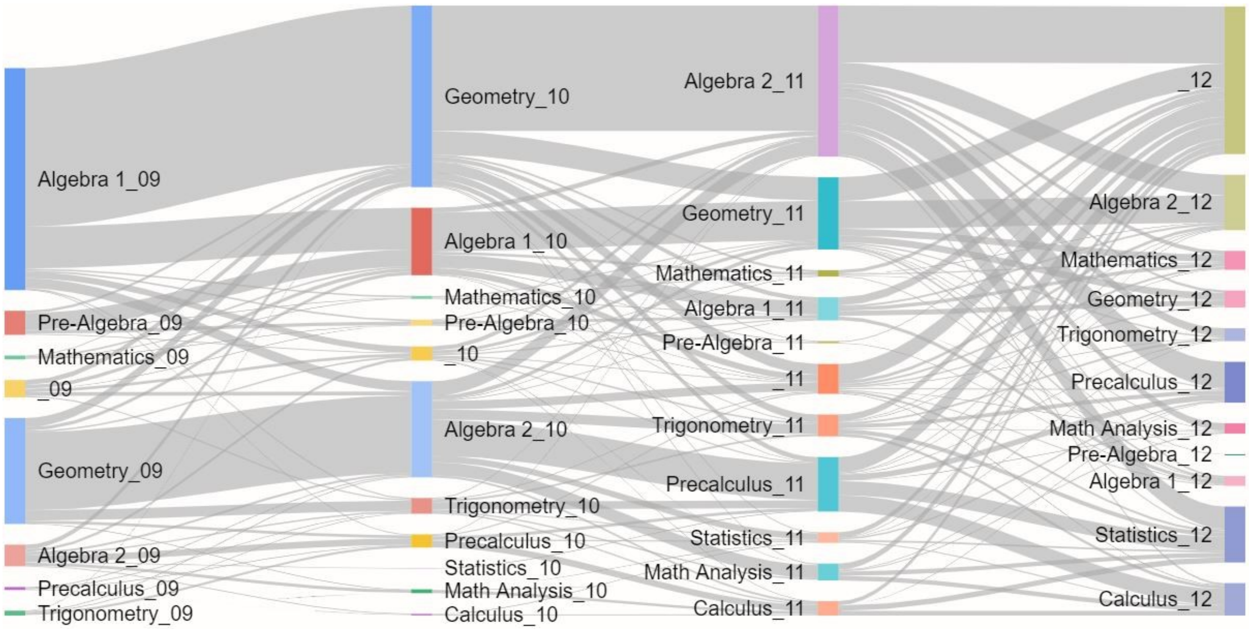
[18] N = 200 equates to 0.00045% of Sample 1.

(3.5%) and freshman year (4.3%). These rates of no math in the senior year are comparable to those found by Finkelstein et al. (2012) in which between a quarter and a third of California high school students took no math in their senior year. Asim et al. (2019) found that approximately a quarter of all California high school seniors did not take a math class in 2016, 2017, and 2018. Finkelstein et al. (2012) found that students with higher levels of math achievement (i.e., had received “A” or “B” grades in 7th grade math) were the least likely to skip math in their senior year, which likely explains why the current sample of community college students has a higher overall rate of no math in the senior year than in the sample used by Asim et al. (2019) since that sample includes students accepted by the University of California and the California State University—students who as a group have very high average levels of academic achievement. Although it was not possible to determine with complete confidence the reason for the absence of a reported math class in a given year, an average of 3.5 math class enrollments were recorded per student, indicating that students’ course information in Sample 1 was reasonably complete and would allow us to draw valid inferences regarding typical math coursework patterns.

Figure 1 also shows another path through these three common courses. This alternate path begins with Algebra 1, followed immediately by Algebra 2, concluding with Geometry. This arrangement of these three courses indicates that for students with a final high school math course of Geometry, their course-taking record must also include additional coursework to ascertain their highest math class completed (since Algebra 2, a key math class, may be taken *before* Geometry).

Examination of students’ high school math course-taking patterns reveals that many more students may be included in the analysis of RQs 2, 3 and 4 by focusing on students’ 11th and 12th grade math coursework. This set of criteria allowed us to nearly triple the size of Sample 2 relative to Sample 1 (adding an additional 810,245 to the original 440,920), increasing statistical power for subsequent analyses. Sample 2 and the criteria for developing it are presented in Table 1 and the Methodology section above.

Figure 1. Sankey Diagram of High School Math Enrollment Patterns



RQ 2: Among students who did not complete Algebra 2 in high school, what is the throughput rate of those who enrolled directly in either a transferable, college-level SLAM or B-STEM-pathway math class at the community college and how does it compare to the throughput rate of those who initially enrolled in Intermediate Algebra at the community college?

We evaluated this question by comparing the throughput rates of three groups of students within the cohort of students who took their first math class at the community college in fall 2019 (i.e., the first semester of AB 705 implementation):

- Students who enrolled in Intermediate Algebra at the community college
- Students who enrolled directly in a transferable, college-level Statistics or Liberal Arts Math (SLAM) class with or without support
- Students who enrolled directly in a B-STEM math class[19] with or without support

These three groups were further subdivided by whether students had <u>not</u> completed Algebra 2 in high school or whether they had completed exactly Algebra 2 as their most advanced math class in high school. These categorizations resulted in a final set of six distinct groups across which one-year throughput could be compared.

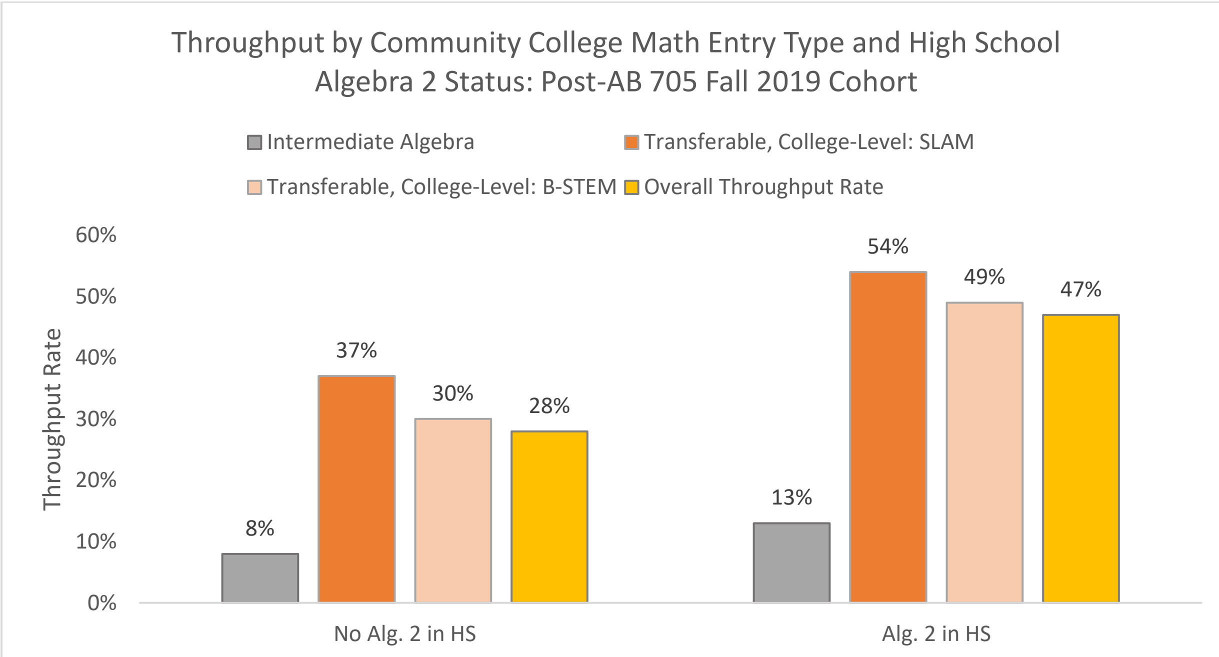
[19] The following courses are categorized as B-STEM math courses: College Algebra (except when specified as Liberal Arts), Business Math, Finite Math, Trigonometry, Precalculus, Calculus, Differential Equations, and Linear Algebra. For examples of typical courses from each category see Appendix C.

The fall 2019 cohort was used to answer this research question because community colleges in California were required to shift assessment and placement procedures and curriculum in response to the passage of AB 705 by fall 2019.[20] One of the effects of AB 705 was to change which students could be placed into Intermediate Algebra. With the implementation of AB 705 in fall 2019, the guidance from the California Community Colleges system office was that students should only be placed into Intermediate Algebra if they had not already completed it in high school and if they were also pursuing a STEM program of study. In response to the requirements of AB 705, most colleges in the system began offering transferable, college-level math placements with concurrent remediation to students who prior to fall 2019 would have been placed in multi-term remediation sequences (Hern et al., 2020). This change represented a significant shift in their models of assessment, placement, and curriculum. By focusing on the fall 2019 cohort, we can compare historical throughput rates to those realized by students in the current and ongoing policy context who are experiencing the results of these widespread and comprehensive changes in placement and curriculum.

Figure 2 and Table 4 below summarize the results of this analysis. **Students who had not completed Algebra 2 in high school were more likely to complete transferable, college-level math within one year if they began directly in a transferable, college-level B-STEM math class rather than in Algebra 2** (30% vs 8%). **Students who had not completed Algebra 2 in high school were also more likely to complete a transferable, college-level course within one year if they began directly in a college-level SLAM course than if they began in Algebra 2** (37% vs. 8%). These results indicate that **students who have not completed Algebra 2 in high school are more likely to complete transferable, college-level math if they begin in transferable, college-level math than if they start in Intermediate Algebra.** This result is true whether they begin in a transferable, college-level B-STEM course or a SLAM math course. As with those who have completed Algebra 2 in high school, direct entry into transferable, college-level math meets the AB 705 standard of maximizing the probability of completing transferable, college-level math with a year of first math attempt.

[20] See http://bit.ly/AB705-Timeline

Figure 2. Throughput by Community College Math Entry Type and High School Algebra 2 Status: Post-AB 705, Fall 2019 Cohort



While it is certainly true that students who have completed Algebra 2 in high school perform better in their community college math classes than their peers who did not successfully complete Algebra 2 in high school, it is not the case that those students who did not complete Algebra 2 in high school and then began their math journey at the community college in Intermediate Algebra fared better than those who entered directly into transferable, college-level coursework. Rather, **students who entered directly in transferable, college-level math, whether it was SLAM or B-STEM, had much higher one-year throughput rates than students who began their community college math sequence by entering Intermediate Algebra**. This finding holds true **regardless of whether the students had successfully completed Algebra 2 in high school.**

Table 4. Sample Size and Throughput by CC Math Entry and High School Algebra 2 Status - Fall 2019 Cohort

	No Algebra 2 in High School		Algebra 2 in High School	
	Throughput	N	Throughput	N
Intermediate Algebra Entry	8%	4,914	13%	2,406
Transferable SLAM Entry	37%	9,102	54%	10,436
Transferable B-STEM Entry	30%	3,664	49%	6,610
Overall Throughput Rate	28%	17,680	47%	19,452

Given that the results for RQ 2 pertain specifically to the fall 2019 cohort of students who experienced the initial impact of the changes associated with the implementation of AB 705, the next section presents a similar analysis for earlier cohorts of students (i.e., pre-fall 2019/AB 705).

RQ 2.1: How do historical patterns of throughput for community college students who did not successfully complete Algebra 2 in high school compare to the throughput results attained after the implementation of AB 705?

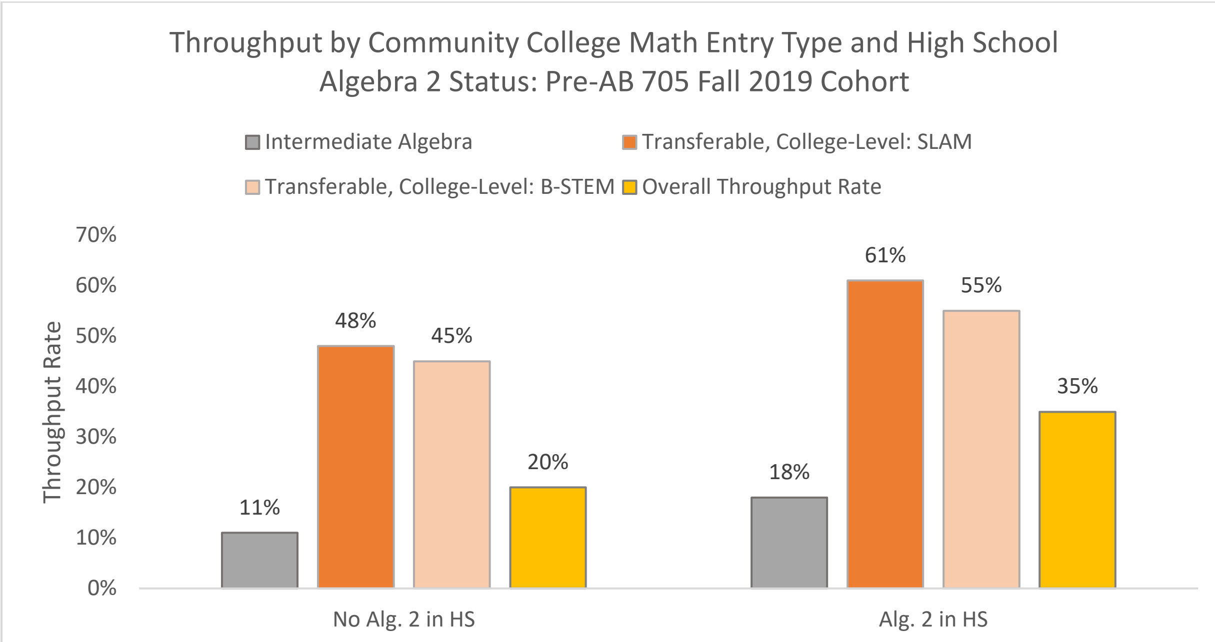
Do the results we see for the fall 2019 cohort of post-AB 705 students equally apply to earlier cohorts who began the math sequence prior to AB 705? These students would have largely experienced an assessment, placement, and curriculum informed by the traditional paradigm of placement testing and multi-term remediation with little opportunity for concurrent or corequisite remediation. To answer this question, we assessed the one-year throughput of students who completed their first math class at the community college between fall 2010 and fall 2018, comparing the results from those fall cohorts to the post-AB 705 fall 2019 cohort evaluated in RQ 2.[21]

As shown in Figure 3 and Table 5 below, prior to the implementation of AB 705 students who had not completed Algebra 2 in high school had higher one-year completion rates when they began their community college math sequence by entering directly into a transferable, college-level math course. **Whether they pursued B-STEM (45%) or SLAM (48%) coursework, beginning in a transferable, college-level class maximized one-year throughput for students who had not completed Algebra 2 in high school relative to those who entered the community college math sequence via Intermediate Algebra (11%).** A similarly large gap exists for students who did complete Algebra 2 as their highest math class in high school; students entering a transferable, college-level SLAM course or B-STEM course achieved higher one-year throughput rates (61% and 55%, respectively) than those whose first math class at the community was Intermediate Algebra (18%). These findings confirm that the post-AB 705 patterns of differential success existed prior to AB 705[22] and that **the effect of AB 705 was to amplify the higher throughput enrollment patterns and reduce lower throughput enrollment patterns.**

[21] Fall cohorts were used to establish a more controlled comparison to the fall 2019 post-AB 705 since there are relatively large and reliable variations in throughput rates depending on the term in which students begin their math sequence (see Appendix D).

[22] And, importantly, prior to the impact of the COVID-19 pandemic.

Figure 3. Throughput by Community College Math Entry Type and High School Algebra 2 Status: Pre-AB 705, Fall 2019 Cohort



Prior to AB 705, assessment, placement, and curriculum structures were having some success in identifying students who had lower likelihood of completing math coursework. However, placing these students into developmental coursework did not have the desired result of increasing their eventual likelihood of completing transferable, college-level math. Rather, to borrow a phrase from Clark (1960), developmental and pre-transfer level placements resulted in a large proportion of students "cooling out" and never successfully completing a transferable, college-level math class.

Table 5. Sample Size and Throughput by CC Math Entry and High School Algebra 2 Status – Pre-AB 705 Cohorts

	Alg. 2 in High School = No		Algebra 2 in High School = Yes	
Community College Entry Point	**Throughput**	**N**	**Throughput**	**N**
Intermediate Algebra	11%	46,826	18%	46,628
College-Level SLAM, transferable	48%	7,827	61%	17,264
College-Level STEM, transferable	45%	7,350	55%	16,924
Overall Throughput Rate	20%	62,003	35%	80,816

When comparing throughput rates between Figures 2 and 3, the lower overall throughput rates of the pre-AB 705 cohorts (Figure 3) are due to the much larger number and proportion of students who began community college math in Intermediate Algebra relative to the much smaller number and proportion who began in Intermediate Algebra after AB 705 went into effect. While it is true that students who had not completed Algebra 2 in high school had lower throughput rates than students who had, those who entered directly into transferable, college-level B-STEM coursework still had higher throughput rates than students who entered into Intermediate Algebra even if they had not successfully completed Algebra 2 in high school. The same pattern was apparent for students entering transferable, college-level SLAM classes.

While the overall pattern of results for pre-AB 705 cohorts was the same as for post-AB 705 cohorts, an intriguing and apparently contradictory pattern emerges when we compare the two sets of cohorts. The overall throughput is higher post-AB 705 for both the Algebra 2 completers (47% vs. 35%) and non-completers (28% vs. 20%), but the pattern reverses when we compare the entry-point subgroups of the two cohorts. For example, Algebra 2 completers who began in a transferable, college-level STEM class had lower throughput post-AB 705 than pre-AB 705 (30% vs. 45%). The Intermediate Algebra and SLAM entry-point subgroups show a similar pattern where post-AB 705 throughput is lower than pre-AB 705, and yet overall throughput of all groups combined is sharply increasing. How is this possible?

This apparent paradox occurs because prior to fall 2019 the dominant entry point for the math sequence in the community college was Intermediate Algebra, which is the entry point with the lowest throughput rate across all terms. In the pre-AB 705 terms, approximately twice as many students started in Intermediate Algebra as started in transferable, college-level math (93,454 vs. 49,365). In fall 2019, after the implementation of AB 705, approximately four times as many students began in transferable, college-level math than in Intermediate Algebra (29,812 vs. 7,320). Thus, the huge shift of students from the low throughput entry point of Intermediate Algebra to the higher throughput entry point of transferable, college-level math substantially increased the overall throughput of the fall 2019 cohort relative to pre-AB 705 cohorts (38% vs. 28%). The increase in overall throughput means that a larger number of students successfully completed transferable, college-level math relative to prior years despite the decline in pass rates and throughput rates for each subgroup.[23] This apparent paradox may help explain how perceptions of the impact of AB 705 can vary strongly depending on one's position and perspective. In any case, the overall volume of successful students increased in fall 2019 as did the overall throughput rates, underscoring the importance of tracking and comparing the performance of entire cohorts, as relying only on pre/post comparisons of subgroups may be misleading.

RQ 3: What is the effect of different levels of high school math course attainment on math throughput at the community college after controlling for variations in high school GPA?

To evaluate this research question, we analyzed Sample 2 with a multivariate logistic regression, allowing us to simultaneously evaluate the association of high school GPA, highest high school math level completed (coded as "prior to Algebra 2," "Algebra 2," or "subsequent to Algebra 2"), and entry point into the community college sequence (i.e., transferable, college-level math or Intermediate Algebra).

[23] This type of counter-intuitive situation where the overall results appear to run counter to the results of the individual groups is known as Simpson's Paradox or the ecological fallacy (see https://plato.stanford.edu/entries/paradox-simpson/).

The overall model was statistically significant, explaining approximately 40% of the variability in math throughput (Nagelkerke $R^2 = .398$, $p < .001$). The results for the factors in the model are presented in Table 6 below.

Table 6. Multivariate Model Predicting Transferable, College-Level Math Throughput

	B	S.E.	Wald	df	Sig.	Odds Ratio
High school GPA	1.233	.007	30,101.173	1	< .000	3.430
Enter at transferable, college-level math	1.898	.007	64,070.512	1	<.000	**6.671**
Highest high school math is prior to Algebra 2	-.113	.013	74.539	1	<.000	.893
Highest high school math is subsequent to Algebra 2	.393	.009	1823.256	1	<.000	1.481
Constant	-5.115	.022	56,052.266	1	<.000	.006

The odds ratios show that beginning postsecondary math in a transferable, college-level class was a powerful factor in predicting math throughput in the first year; the effect is nearly equivalent to a difference of two grade points in a student's cumulative high school GPA (e.g., a "C" student in high school who entered directly into a transferable, college-level math class would have about the same likelihood of throughput as an "A" student who began their college math coursework in Intermediate Algebra). After taking into account the influence of cumulative high school GPA and highest math class in high school, **students who enter directly into transferable, college-level math are 6.7 times more likely to complete transferable, college-level math in their first year than are students who begin in Intermediate Algebra**, as shown in the cells with bold text in Table 6**.**

Given that the focus of this paper is on the role of high school Algebra 2 in preparing students for success in community college math, we also developed a second model that restricted the sample to students who had either completed Algebra 2 in high school or who had completed only a pre-Algebra 2 class (including Geometry, if taken prior to Algebra 2). This second model (shown in Table 7) replicated the finding from the initial model, showing that entry into transferable, college-level math at the community college is greatly advantageous for all high school students. **Even students who have not completed higher levels of math coursework in high school are over six times more likely to complete transferable, college-level math when allowed direct access to those classes.**

Table 7. Odds Ratios and Coefficients for Variables in the Model Predicting Likelihood of Throughput

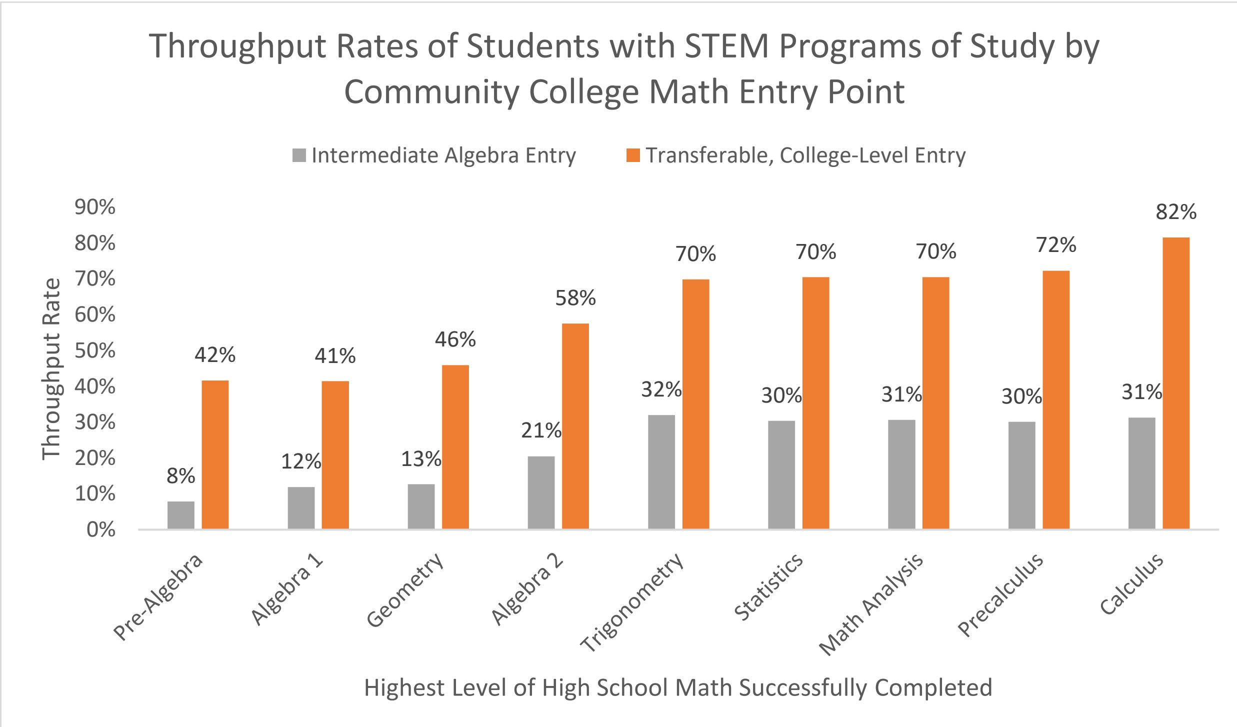
Variables in the Equation	B	S.E.	Wald	df	Sig.	Odds Ratio
High School GPA	1.042	0.009	13,876.68	1	< 0.001	2.834
Enter at transferable, college-level math	1.851	0.009	44,512.17	1	< 0.001	**6.366**
High School Math Level	-0.012	0.003	20.283	1	< 0.001	0.988
Constant	-4.487	0.024	35,955.47	1	< 0.001	0.011

RQ 4: Among students who have declared a STEM program of study and who have not completed Algebra 2 in high school, which placement—transferable, college-level math vs. Intermediate Algebra—maximizes the probability of completing a STEM pathway math class at the community college?

Using students' declared program of study, we identified a subset of 52,430 students from Sample 2 who had indicated their intent to pursue a STEM program at the community college and who either began in Intermediate Algebra or in a college-level, transferable STEM math class at the community college. We evaluated these students' math throughput disaggregated by their highest level of math in high school and by their initial math enrollment at the community college (i.e., Intermediate Algebra vs. transferable, college-level math). The results are shown in Figure 4 below.

Students who declared an intent to pursue a STEM program of study had much greater throughput when allowed to begin their math studies at the community college in a transferable, college-level math class, regardless of their math attainment level in high school (see also Willett et al., 2018). Even students who had only successfully completed Pre-Algebra had a 42% throughput rate when allowed to access transferable, college-level math classes at the community college compared to an 8% throughput rate if they began in Intermediate Algebra. This large gap was present for students at all levels of high school math; those **students who have declared a STEM program of study who begin in transferable, college-level math have two to five times the throughput rate of students with the same math background who begin in Intermediate Algebra** at the community college.

Figure 4. Throughput Rates of Students with STEM Programs of Study by College Math Entry Point and Highest Math Completed in High School



An examination of Figure 4 suggests that students' high school math attainment can be sorted into three groups according to their likelihood of successfully completing transferable, college-level math at the community college:

1. Completed a math class subsequent to Algebra 2 in high school
2. Successfully completed Algebra 2 in high school
3. Highest level of successful math completion in high school is lower than Algebra 2

Students in Group 1 have the highest average throughput rate, while those in Group 2 have a moderate average throughput rate, and students in Group 3 have the lowest average throughput rates. The intensity and level of additional support afforded to students could be scaled accordingly. AB 705 mandates that students begin in a course that maximizes their likelihood of completing transferable, college-level math within one year. Figure 4 shows that starting in a transferable, college-level course produces higher completion than starting in Intermediate Algebra, regardless of high school math preparation. **These data suggest that high school math attainment should not be used to block access to transferable, college-level STEM math classes. Instead, it could be used to assign students to varying intensities of additional support, with those in Group 3 receiving proactive, high intensity support.**

Limitations

There are likely important observations that are missing from the analytical samples used in this study. For example, students may have availed themselves of additional math preparation outside of high school that would not be captured in their high school records. It is possible that some students may have been missing important data points that would have changed our estimation of their highest math level completed and/or that students who were excluded because of missing data may have been systematically different from those who were included. The study's large sample size does provide a something of a hedge against these concerns, however.

Coding of high school math classes necessitated some assumptions such as the equivalency of integrated math (IM) courses with traditional math courses (i.e., IM 1 = Algebra 1; IM 2 = Geometry; IM 3 = Algebra 2). Additional research is needed to validate this equivalency (see Appendix E for author's analysis of equivalency).

The students included in this sample represent that segment of California high school students who go on to the community college. Students who matriculate directly to a university or who choose not to attend college may have different profiles and outcomes.

The paper is primarily framed around the requirements of AB 705, however, completing a single college-level mathematics course is not sufficient for most STEM majors. For example, engineering students are typically expected to complete Calculus I, Calculus II, Calculus III, Linear Algebra, and Differential Equations prior to transfer. Additional research is needed on the implications of AB 705 on longer-term math sequence completion as well as graduation and transfer outcomes.

The fact that the COVID-19 pandemic took effect approximately halfway through the spring 2020 semester may have depressed throughput rates for the first post-AB 705 cohort (i.e., the one that began in fall 2019). On the other hand, according to the Chancellor's Office Data Mart, the average pass rate for math classes in spring 2020 actually increased relative to spring 2019, even when counting all "excused withdrawals" as non-passing grades (58.7% vs. 55.7%). In any case, spring 2020 was an unusual time in many regards and the results of this study should be replicated with future cohorts.

Finally, the estimates of math course-taking in high school in this paper likely represent an undercount of overall math course-taking, as some high school students, particularly juniors and seniors, may be taking math courses outside their regular high school schedule (e.g., test prep classes, dual/concurrent enrollment in college courses while in high school).

Discussion

One of the most powerful predictors of transferable, college-level math completion is under the control of community colleges: placing students directly into transferable, college-level math. The influence of placement is more powerful than the influence of the highest math class completed in high school; it is approximately equivalent to a two-point change in high school GPA (e.g., given the same level of high school math preparation students with a 4.0 GPA who begin in Intermediate Algebra have about the same average throughput rate as students with a 2.0 GPA who begin in transferable, college-level math). These findings are valid for students who are pursuing STEM programs of study as well as for those pursuing non-STEM programs. **The implication for students who have not completed Algebra 2 in high school and who are pursuing STEM programs of study at the community college level is clear: they are best served by enrolling directly in transferable, college-level STEM-oriented math classes.** These results hold true for all students at all achievement and math attainment levels. And because just 18% of fall 2019 first-time math students enrolled in a corequisite class (Cuellar Mejia et al., 2020; Snell, 2021) throughput rates have room to climb further as more colleges implement additional enhanced and corequisite gateway classes while tuning pedagogy and support options to boost student success in this new environment.

The findings of this paper underscore the critical importance of student engagement with high school math, suggesting that concerted efforts should be made to keep students engaged in classes that increase numeracy and quantitative skills throughout high school. As Adelman (1999) noted, students who complete higher levels of math while in high school (i.e., beyond Algebra 2) double their odds of going to college and eventually completing their bachelor's degree. Note that we are not calling for a change to college acceptance criteria; rather, we reiterate the suggestion made by Finkelstein et al. (2012) to establish a statewide policy ensuring that all students stay engaged with quantitative coursework throughout high school. While such policies do currently exist, they are local policies affecting only some high schools and benefitting only some students, leaving the door open for uneven and inequitable preparation of students for college. A statewide policy would ensure equitable opportunities for all students to progress through a meaningful and rigorous high school math curriculum, positioning them for success in the field of their choosing.

A clear understanding of high school course-taking patterns makes it possible to evaluate the impact of different course-taking on community college math success. While students who complete less math in high school do have lower success rates in subsequent community college math classes, their relatively lower rates of success do not in and of themselves indicate that placement into Intermediate Algebra is more desirable than placement into a transferable, college-level math class with or without corequisite support. When we compare students with similar high school GPAs who did not complete Algebra 2 in high school, **those who begin in a transferable, college-level math class are 6.7 times more likely to complete a transferable, college-level math class within one year than those who begin their community college math coursework in Intermediate Algebra.** Whether students are following a statistics and liberal arts math (SLAM) pathway or a STEM-oriented math pathway, we find that students who begin directly in transferable, college-level math classes have much greater throughput than their peers with similar levels of high school math attainment who begin their community college math journey in Intermediate Algebra.

Although it can be difficult to see when using standard measures of student achievement such as pass rates, **the negative effect of placing students into non-transferable, college-level math classes is clear when throughput rate is used to assess progress and completion.** Throughput rates provide a way to evaluate the progression of students and their success in key gateway math classes in a single metric. Simply evaluating pass rates in specific classes does not provide a perspective capable of truly comprehending how to maximize students' completion of gateway math courses.

The analyses in this paper use throughput rates to evaluate the performance of entire cohorts of first-time math students. This perspective illuminates how the shift in student placement away from Intermediate Algebra and multi-term developmental sequences to direct enrollment in transferable, college-level math results in much greater numbers of students completing transferable, college-level math than ever before. Although interviews with math faculty have revealed than many are skeptical of the benefits of placing students directly into transferable, college-level math (Cuellar Mejia et al., 2020; Ngo et al., 2021; White et al., 2021), the data on student performance and progression are clear, compelling, and deserving of widespread review and discussion among math faculty. The difference between the throughput students achieve when placed directly into transferable, college-level math relative to Intermediate Algebra is so great that even if broad access to transferable, college-level math classes results in modest declines in the pass rates of individual courses, the choice that maximizes math throughput is clear: **direct access to transferable, college-level math classes maximizes the likelihood that students will complete a transferable, college-level math class within one year by eliminating attrition from multi-term developmental sequences and by immediately engaging students in challenging, rigorous, and relevant curriculum**.[24] Importantly, these benefits of direct access extend to all students, regardless of high school GPA, highest math completed in high school, or program of study.

Recommendations

Given our findings, we recommend that colleges direct all students to begin their math studies in transferable, college-level math classes regardless of whether they completed Algebra 2 (or the equivalent) in high school. In addition to expanding access to transferable, college-level math, colleges should offer concurrent remediation options as well as additional support for students with lower high school GPAs and/or lower levels of math attainment in high school.

[24] Melguizo et al. (2019) and Willett (2015) found that the majority of incoming California community college students have historically been required to repeat math courses they had already passed in high school with students of color being the most likely to be required to repeat math classes.

Additional support could be scaled according to students' high school math attainment:

High School Math Profile	Typical Throughput Results	Recommended Support
Successfully completed a high school math class subsequent to Algebra 2, (e.g., precalculus) with at least a "C-"	Highest average throughput rate	Transferable, college-level math placement; Additional support optional
Successfully completed Algebra 2 in high school (but not higher) with at least a "C-"	Middling throughput rate	Transferable, college-level math placement; Moderate level of additional support required
Successfully completed less than Algebra 2 in high school	Lowest average throughput rate	Transferable, college-level math placement; Highest intensity of additional support needed, including holistic support for non-academic issues

The types of support available will vary from college to college, as will the exact nature of what constitutes a moderate level of support relative the highest intensity of additional support. Typically, concurrent remediation coursework would comprise a minimum level of required support with additional levels of support (e.g., coaching, tutoring, intrusive advising, and real-time performance monitoring and feedback) possibly being made available. The Accelerated Study in Associate Programs (ASAP)[25] intervention in the CUNY system provides an example of what holistic support can look like, targeting four areas for proactive and sustained support efforts:

- Student services: Students receive dedicated tutoring, career services, and comprehensive advisement from an advisor with a small caseload
- Course enrollment support: Access to enroll in blocked/linked courses and priority registration; Enrollment in seminars on goal-setting and study skills
- Requirements and messages: Students are required to attend college full-time and graduate within three years
- Financial supports: Tuition, transportation, and textbooks are covered

The ASAP intervention nearly doubled the three-year graduation rate at those institutions implementing the program (Scrivener et al., 2015).

Finally, if not already providing this information, colleges may wish to revise their website and other communications to students to provide and compare the average transferable, college-level math completion rates (i.e., throughput rates) of students who start in transferable,

[25] https://www1.cuny.edu/sites/asap/about/

college-level math relative to those who start in Intermediate Algebra, disaggregated by the highest math class completed in high school (see Figure 4).[26]

Future Research

An implication of the current upward trend in math throughput rates is that recent innovations in community college math instruction (in terms of assessment, placement, curriculum, and pedagogy) are resulting in large gains in the number and percentage of students completing transferable, college-level math. While much of these gains are doubtless related to the broad, structural changes mandated by AB 705, future research should examine in greater detail how and to what extent specific innovations (e.g., placement practices, just-in-time remediation, self-remediation, enhanced classes, corequisite remediation, embedded tutoring, required supplemental instruction, faculty professional development, equity initiatives) are uniquely or in combination supporting or promoting increased math throughput. There is still much to learn about how to best support students of varying backgrounds in the challenging work of completing transferable, college-level math courses. Although recent increases in access and throughput are compelling, there is promise of further improvement as we develop our knowledge of how to better support students with varying math backgrounds in their progression toward completing their educational goals.

Additionally, it is crucial to understand the implications for equity of evolving math pathways. While other recent research (e.g., Brohawn et al., 2021; Cuellar Mejia et al., 2020; Hayward et al., 2019) shows that these reforms have closed equity gaps in access to transferable, college-level math, additional research is needed to highlight positive outliers and practices that are associated with eliminating equity gaps in math outcomes. Questions include: Which pathways and practices have been most effective in closing equity gaps not just in access but in learning and completion? What are the downstream effects of changes in access to key gateway math classes? What are the postsecondary implications of variability across high school districts in promoting continuous engagement with math?

Work in high schools to develop math pathways that connect to students' aspirations, postsecondary pathways, and career goals by clarifying the relevance and importance of developing math skills is gaining momentum (Daro & Asturias, 2019; Moussa et al., 2020). UCLA's *Introduction to Data Science* (IDS) class, implemented in 52 California high schools, is one prominent example (https://www.introdatascience.org/). IDS teaches students to work critically with data, learning how to code and conduct statistical analysis with industry-standard programs. There are a number of important questions to investigate regarding this new, more contextualized curriculum: Do these courses increase math engagement for high school students

[26] Throughput rates could be included on assessment and placement webpages. For Californica colleges this information could complement the disaggregated assessment and placement reporting requirements of AB 1805 (Irwin). California community colleges could also consider highlighting or linking to the new statewide dashboard developed by the Chancellor's Office in partnership with the RP Group's Multiple Measures Assessment Project (https://bit.ly/CalCommCollege-Gateway-Completion-Dashboard).

who might otherwise skip math in their senior year? Do these high school math pathways increase student success and equitable achievement in postsecondary math coursework?[27]

Finally, the results presented here are congruent with findings from other research indicating that students who complete remedial coursework in community college improve their procedural math knowledge but not their conceptual math knowledge, and that those gains in procedural math knowledge do not increase students' odds of success in higher-level math classes, which primarily demand conceptual fluency (Quarles & Davis, 2016). Further research could explore variations in the degree to which math courses (including Intermediate Algebra) tend to be either procedurally-oriented—that is, they tend to focus on teaching a fixed sequence of steps to solve a problem—or conceptually-oriented, in that they develop students' understanding of concepts in order to solve problems more flexibly. The variability in the procedural to conceptual axis could be analyzed both across different courses and across sections of the same course as a way to improve our understanding of how to use these important aspects of math instruction more intentionally to increase student engagement and success.

[27] The intersegmental research into these questions and others would be facilitated by developing Course Group State Codes specific to these courses (currently IDS courses are classified along with other Statistics courses).

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Appendix A

Analysis of the Association between High School GPA and Highest Math Completed

Figure A1. Association of High School GPA with Highest Math Completed – High School Longitudinal Study of 2009 (US Department of Education, 2021)

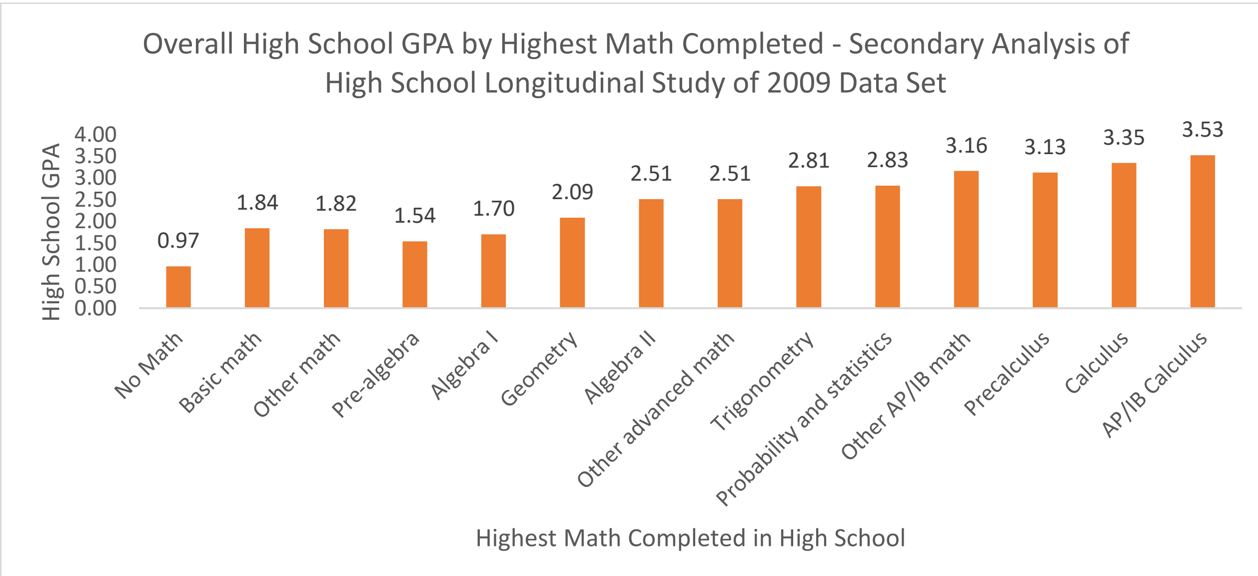


Table A1. Overall High School GPA (X3TGPATOT) and Sample Size by Highest Math Completed in High School (X3THIMATH) – Secondary Analysis of the High School Longitudinal Study of 2009

	Overall High School GPA	Sample Size
No math successfully completed	0.97	416
Basic math	1.84	127
Other math	1.82	205
Pre-algebra	1.54	194
Algebra I	1.70	1,250
Geometry	2.09	2,058
Algebra II	2.51	4,650
Other advanced math	2.51	2,499
Trigonometry	2.81	1,288
Probability and statistics	2.83	1,016
Other AP/IB math	3.16	331
Precalculus	3.13	4,172
Calculus	3.35	1,164
AP/IB Calculus	3.53	2,500
Average/Total	**2.70**	**21,870**

Figure A2. Cumulative High School GPA by Highest Math Course Completed in High School – Current Data Set

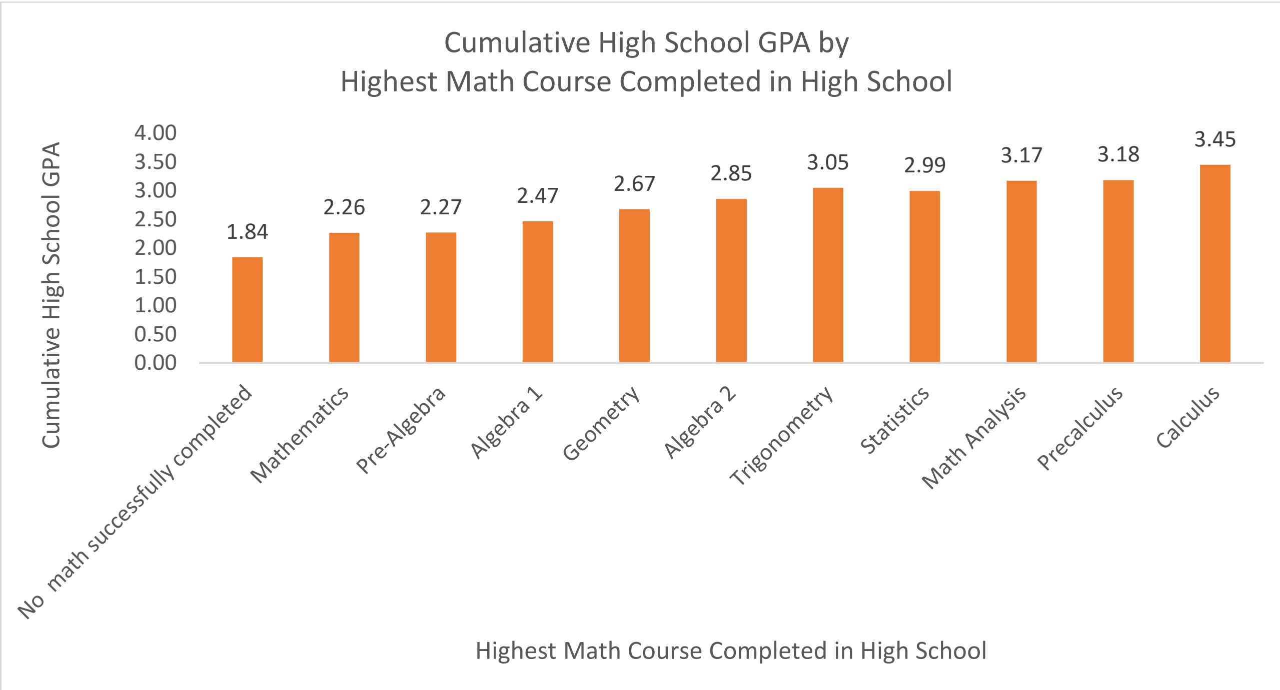


Table A2. Overall High School GPA and Sample Size by Highest Math Completed in High School– MMAP Data Set

	Overall High School GPA	**Sample Size**
No math successfully completed	1.84	30,309
Arithmetic	2.26	3,881
Pre-Algebra	2.27	3,255
Algebra 1	2.47	37,803
Geometry	2.67	49,655
Algebra 2	2.85	72,952
Trigonometry	3.05	11,288
Statistics	2.99	23,429
Math Analysis	3.17	8,834
Precalculus	3.18	39,822
Calculus	3.45	24,530
Average/Total	**2.78**	**305,758**

In both the national data set of the High School Longitudinal Study of 2009 and in MMAP's own data set there was a strong, positive relationship between high school GPA and highest math completed in high school (R^2 = .94 and R^2 = .96, respectively).

Appendix B

Programs Coded as STEM

Table B.1 shows the Taxonomy of Programs (TOP) code areas that were categorized as STEM.[28] Any student with a program of study or major associated with these TOP code areas was included in the STEM-oriented subgroup. Programs are sorted in descending order of size with the top 15 areas accounting for about 96% of STEM students. After grouping together related TOP code areas, there are essentially six large areas in which STEM-oriented students in the California Community Colleges system are enrolled:

- Biology (26.9%)
- Engineering (23.4%)
- Math (10.2%)
- Computer Science (16.3%)
- Chemistry (4.3%)
- Physics (2.9%)

Additionally, there is a combination area that spans Biological and Physical Sciences and Mathematics and comprises an additional 9.8% of STEM-oriented students. These seven areas together cover approximately 94% of STEM-oriented students. For additional discussion of classifying STEM programs at the community college see Lundy-Wagner & Chan (2016).

[28] The Taxonomy of Program (TOP) is a system of numerical codes used by the California Community Colleges system to collect and report information on similar programs across different colleges throughout the state, similar to the national Classification of Instructional Programs (CIP) codes (https://bit.ly/TOP-Code-Manual).

Table B1. Programs Coded as STEM in Data Set for RQ4 with Frequency Data and Code Values

Taxonomy of Programs (TOP) Title	TOP Code	Similar CIP	Classification of Instructional Programs (CIP) Analog Title	N	Percent
Biology, General	0401.00	260101	Biology/Biological Sciences, General.	17,369	23.43%
Engineering, General (requires Calculus) (Transfer)	0901.00	140101	Engineering, General.	12,821	17.30%
Mathematics, General	1701.00	270101	Mathematics, General.	7,572	10.22%
Biological and Physical Sciences (and Mathematics)	4902.00	300101	Biological and Physical Sciences.	7,240	9.77%
Computer Science (Transfer)	0706.00	110101	Computer and Information Sciences, General.	4,651	6.27%
Architecture and Architectural Technology	0201.00	40200	Pre-Architecture Studies.	3,442	4.64%
Information Technology, General	0701.00	110101	Computer and Information Sciences, General.	3,323	4.48%
Computer Programming	0707.10	110201	Computer Programming/Programmer, General.	3,312	4.47%
Chemistry, General	1905.00	400501	Chemistry, General.	3,153	4.25%
Electronics and Electric Technology	0934.00	144701	Electrical and Computer Engineering.	1,977	2.67%
Biotechnology and Biomedical Technology	0430.00	150401	Biomedical Technology/Technician.	1,900	2.56%
Engineering Technology, General (requires Trigonometry)	0924.00	140103	Applied Engineering.	1,653	2.23%
Physics, General	1902.00	400801	Physics, General.	1,303	1.76%
Physical Sciences, General	1901.00	400101	Physical Sciences, General.	848	1.14%
Other Engineering and Related Industrial Technologies	0999.00	150699	Industrial Production Technologies/Technicians, Other.	579	0.78%
Computer Software Development	0707.00	110201	Computer Programming/Programmer, General.	495	0.67%
Zoology, General	0407.00	260701	Zoology/Animal Biology.	443	0.60%
Geology	1914.00	400601	Geology/Earth Science, General.	315	0.42%
Environmental Science	0301.00	30104	Environmental Science.	274	0.37%
Astronomy	1911.00	400201	Astronomy.	268	0.36%
Other Information Technology	0799.00	110899	Computer Software and Media Applications, Other.	226	0.30%
Geography	2206.00	304101	Environmental Geosciences.	171	0.23%

Taxonomy of Programs (TOP) Title	TOP Code	Similar CIP	Classification of Instructional Programs (CIP) Analog Title	N	Percent
Laboratory Science Technology	0955.00	410101	Biology/Biotechnology Technology/Technician.	105	0.14%
Computer Systems Analysis	0707.30	110501	Computer Systems Analysis/Analyst.	94	0.13%
Oceanography	1919.00	400607	Oceanography, Chemical and Physical.	90	0.12%
Other Biological Sciences	0499.00	269999	Biological and Biomedical Sciences, Other.	86	0.12%
Other Architecture and Environmental Design	0299.00	40299	Architecture, Other.	61	0.08%
Telecommunications Technology	0934.30	150305	Telecommunications Technology/Technician.	56	0.08%
Electron Microscopy	0934.70	150404	Instrumentation Technology/Technician.	49	0.07%
Microbiology	0403.00	260499	Cell/Cellular Biology and Anatomical Sciences, Other.	47	0.06%
Botany, General	0402.00	260301	Botany/Plant Biology.	41	0.06%
Energy Systems Technology	0946.10	144801	Energy Systems Engineering, General.	32	0.04%
Ocean Technology	1920.00	303201	Marine Sciences.	29	0.04%
Chemical Technology	0954.00	410301	Chemical Technology/Technician.	24	0.03%
Anatomy and Physiology	0410.00	260901	Physiology, General.	16	0.02%
Other Physical Sciences	1999.00	409999	Physical Sciences, Other.	16	0.02%
Earth Science	1930.00	303801	Earth Systems Science.	14	0.02%
Plastics and Composites	0954.20	150607	Plastics and Polymer Engineering Technology/Technician.	7	0.01%
Other Mathematics	1799.00	270199	Mathematics, Other.	5	0.01%
Natural History	0408.00	261303	Evolutionary Biology.	4	0.01%
E-Commerce (Technology emphasis)	0709.10	110801	Web Page, Digital/Multimedia and Information Resources Design.	4	0.01%
Instrumentation Technology	0943.00	150404	Instrumentation Technology/Technician.	3	0.00%
Petroleum Technology	0954.30	150903	Petroleum Technology/Technician.	2	0.00%

Appendix C

Correlations among Overall Cumulative High School GPA by Grade Level

Table C1. Correlations of Cumulative High School GPA across Grade Levels

		9th Grade Cumulative GPA	10th Grade Cumulative GPA	11th Grade Cumulative GPA	12th Grade Cumulative GPA
9th Grade Cumulative GPA	Pearson Correlation	1.00*	.923**	.871**	.838**
	Sig. (1-tailed)	n/a	.000	.000	.000
	N	1,046,365	834,159	750,011	678,576
10th Grade Cumulative GPA	Pearson Correlation		1.00*	.942**	.904**
	Sig. (1-tailed)		n/a	.000	.000
	N		1,142,096	896,867	799,349
11th Grade Cumulative GPA	Pearson Correlation			1.00*	.955**
	Sig. (1-tailed)			n/a	.000
	N			1,199,250	924,656
12th Grade Cumulative GPA	Pearson Correlation				1.00*
	Sig. (1-tailed)				n/a
	N				1,155,519

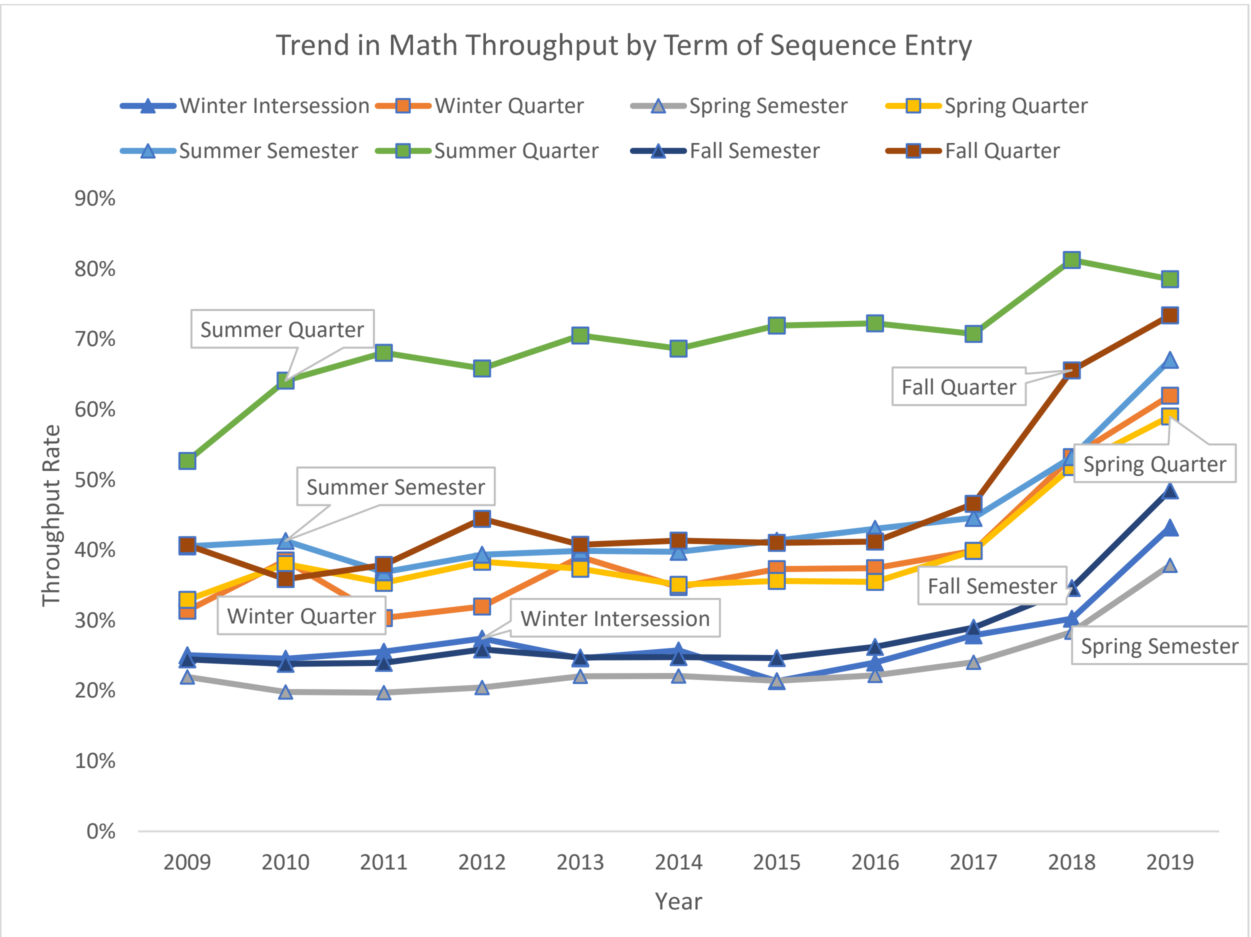
* Each grade's cumulative GPA is perfectly correlated with itself by definition, therefore statistical significance is not germane.
** Correlation is significant at the 0.001 level (1-tailed).

Appendix D

Effect of Sequence Start Term on One-Year Throughput Rates

While math throughput has risen for all students across all term types, students who begin their math coursework in the quarter system realize the highest rates of math throughput within one year. The only semester-based term that has rates comparable to those of students in the quarter system is the summer semester. Students beginning their math coursework in the spring semester reliably have the lowest average throughput rate for either term type (i.e., quarter or semester).

Figure D1. Trend in One-Year Math Throughput Disaggregated by Term of Sequence Entry



Appendix E

Integrated Math and Traditional Algebra 1-Geometry-Algebra 2 Sequences

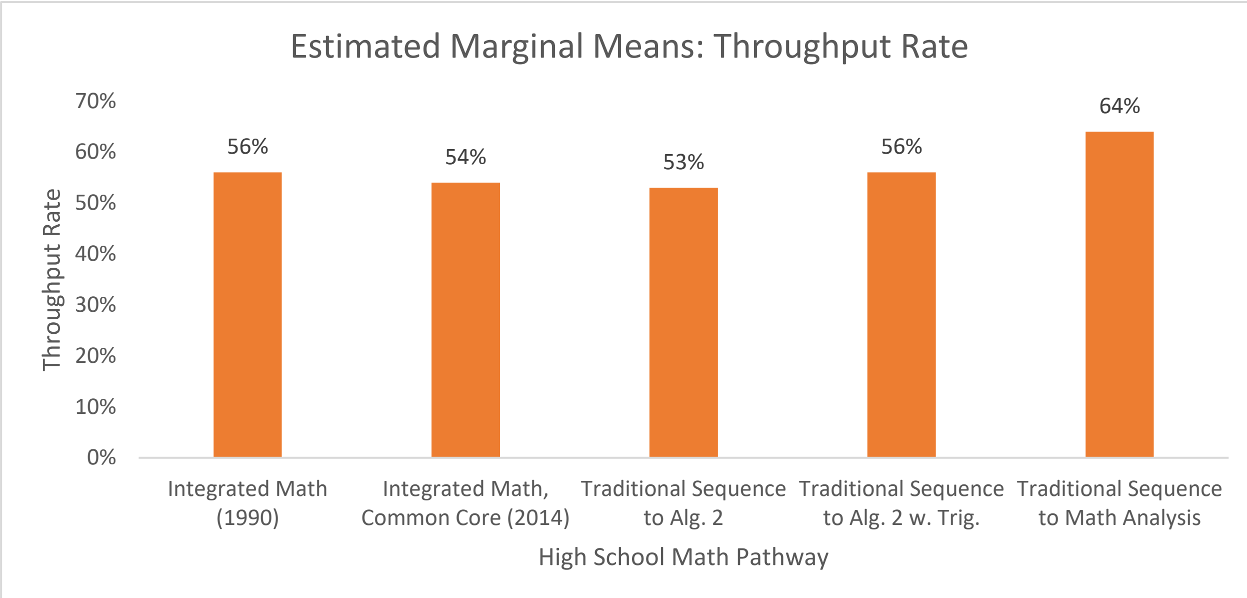
This appendix explores whether students who complete the newer integrated math sequence in high school have different throughput rates at the community college than students who follow the traditional Algebra 1-Geometry-Algebra 2 sequence. Five types of high school math pathways were examined:

1. Integrated Math (1990): A long-standing version of integrated math that preceded the common core integrated math curriculum.
2. Integrated Math Common Core (2014): The common core version of integrated math curriculum, implemented in 2014.
3. Traditional Sequence – Algebra 2: A traditional math sequence that includes Algebra 1 and Geometry, culminating in Algebra 2.
4. Traditional Sequence – Algebra 2 with Trigonometry: A traditional math sequence that includes Algebra 1 and Geometry, culminating in Algebra 2 with Trigonometry.
5. Traditional Sequence – Math Analysis: A traditional math sequence that includes Algebra 1 and Geometry, culminating in Math Analysis.

To evaluate the degree to which these varying high school math pathways were equivalent in preparing students to be successful in college math courses, we compared the one-year throughput among cohorts of students with differing high school math pathways whose highest-level high school math class completed was the culminating class of one of the five sequences outline above. Additionally, in order to give students sufficient time to navigate the recently implemented integrated math sequence, we focused on students who took their first college math class from summer 2018 through summer 2019. We developed a multivariate general linear model (GLM) to compare performance across these five pathways while statistically controlling for differences in high school GPA and community college math pathway taken (i.e., B-STEM or SLAM).

The GLM analysis provides the estimated marginal means for throughput across the five math pathway cohorts, controlling and adjusting for differences in high school GPA and math pathway taken at the community college. The results suggest that there are not large differences in throughput among these generally equivalent high school math pathways (see Figure E1 below). The one exception is the Math Analysis pathway, which had a much higher average throughput rate (i.e., estimated marginal mean) than the other four pathways (8 to 11 percentage points higher). The traditional sequence to Math Analysis option was, however, the least common of the five math pathways, while the traditional sequence to Algebra 2 option was the most common.

Figure E1. Estimated Marginal Means of Throughput Rates for Five High School Math Pathways



Research and Planning Group for California Community Colleges

The RP Group strengthens the ability of California community colleges to discover and undertake high-quality research, planning, and assessments that improve evidence-based decision-making, institutional effectiveness, and success for all students.

Author

Craig Hayward, Ph.D.

www.rpgroup.org

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